

# FABRICATION OF A PROTOTYPE MEDIUM-BETA, 700 MHz APT SUPERCONDUCTING RF CAVITY WITH INDUSTRY\*

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## Abstract

We have designed and fabricated a prototype  $\beta = 0.64$ , 700 MHz, 5-cell superconducting cavity in support of the Engineering Development and Demonstration (ED&D) effort for the Accelerator Production of Tritium (APT) project. The design incorporates all of the features of the production cavities. To develop future potential U.S. suppliers for the production cavities, a technology transfer program was initiated. In the first phase of the program the U.S. suppliers are using LANL supplied tooling, expertise, and niobium to fabricate the same prototype cavity. This paper addresses our experience in the fabrication of the ED&D cavity. It also describes interactions with various industries involved in the fabrication of other cavity components.

## 1 INTRODUCTION

An extensive ED&D effort is underway at Los Alamos National Laboratory (LANL) in support of the Preliminary and Final Design of the APT project. One of the goals of ED&D is to demonstrate performance of superconducting RF (SCRF) cavities to be used in the high-intensity proton linac, to assess difficulties in manufacturing large number of such cavities, and to optimize the final design. General Atomics (GA), selected by DOE as a partner to the prime industrial contractor for the APT project, is actively involved in ED&D program as a member of the SCRF team, serving as a liaison between LANL and industry.

## 2 ED&D CAVITY DESIGN

The design of ED&D medium- $\beta$  SCRF cavity is described in detail in a paper submitted by to this conference [1]. The cavity is made from high-purity bulk niobium (Nb) of RRR > 250. Each cavity has a system of two tuners that allow cavity tuning at the operating temperature of 2.15 K. In addition, special bulkhead-bellow assemblies are provided to support the LHe vessel. A computer generated 3D view of the cavity is depicted in Fig 1. A detailed statement of work (SOW) and manufacturing drawings based on this design, were made available to potential cavity manufacturers.

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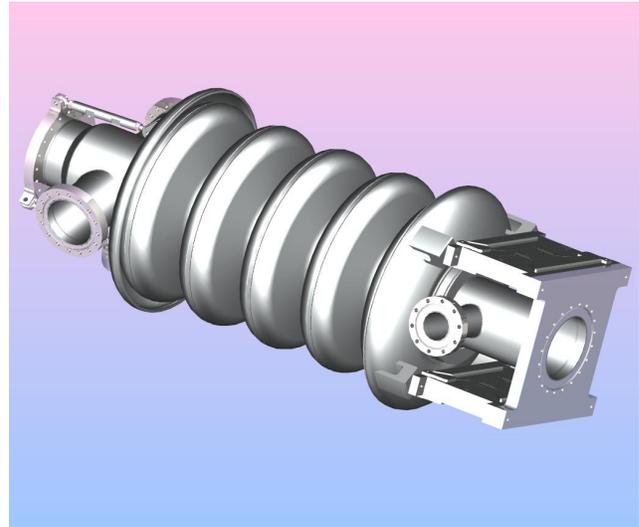


Figure 1. Computer generated layout of the medium- $\beta$  SCRF cavity. Two tuners are visible on the right-side. Ports for power coupler are located on the left-side.

In addition, in August, 1998, the LANL SCRF team completed fabrication of the first five-cell, medium- $\beta$  cavity prototype. The valuable experience gained during this exercise is being transferred to industry.

## 3 MANUFACTURING OF THE CAVITY

Over the past twenty years, a great wealth of experience in manufacturing superconducting cavities has been accumulated at various laboratories and some industries around the world [2]. Most of this experience is related to fabrication of SCRF cavities for electron accelerators. However, little experience exists in fabrication of medium- $\beta$  SCRF cavities for proton accelerators. The present scale of accelerator projects such as APT requires delivery of several hundred SCRF cavities. For such large projects to succeed, industrial participation is mandatory. Therefore, from the beginning of the ED&D program, industry has been included in the process of manufacturing prototype cavities. This process was structured in the following way:

- Identify qualified suppliers of high-quality Nb material for cavity manufacturing
- Identify qualified suppliers of special subassemblies (such as Titanium (Ti) bulkheads-bellows subassemblies and tuners)

- Acquire the world's best SCRF cavity for the ED&D program through a competitive bid process, open to all qualified manufacturers.
- Transfer this technology to U.S. industry

### 3.1 Nb Material

The quality of Nb sheet for SCRF cavity fabrication is one of the most important factors in determining the final performance of the cavity. Therefore, a special material specification was developed that defined impurity levels, material and electrical properties including RRR value, and provided requirements for finished Nb sheets. Today, industry is able to deliver high-quality material with  $RRR > 250$  that satisfies such stringent requirements. Three qualified suppliers of Nb sheets were identified. Each supplier has implemented a Quality Assurance QA program approved by the purchaser to ensure the quality of supplier materials. In addition, the RRR measurements were performed on supplied samples by the independent certified laboratory to validate the Nb sheets.

### 3.2 Special Titanium Bulkhead-Bellow Subassemblies

The ED&D SCRF cavity design calls for Ti vessel to contain LHe. The choice of Ti was made for the following reasons:

- Coefficient of thermal expansion (CTE) for Ti is almost the same as for Nb
- Electron-beam (EB) weldability of Ti to Nb
- Immunity of Ti to residual magnetic field

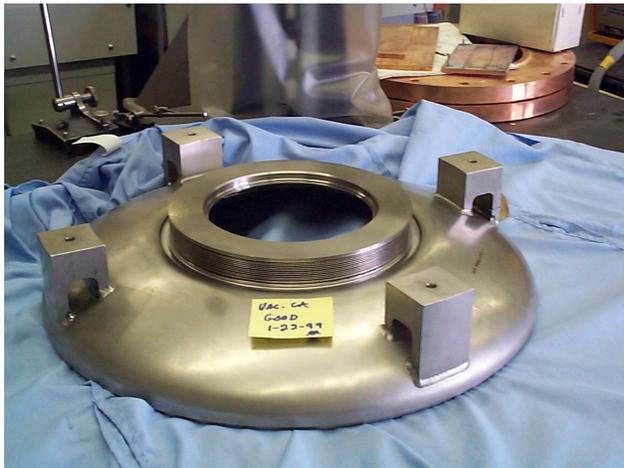


Figure 2. Special titanium bulkhead-bellow subassembly manufactured by industry.

Because of the limited space between the power coupler flange and the end cell, special edge-welded bellows were designed and fabricated by industry. One of the requirements was that the bellows integrity would survive 15,000 full-strokes cycles (assumed lifetime) at operating temperature of 2.15 K. Recent tests performed at Thomas

Jefferson National Accelerator Facility at 77 K showed that bellows survived up to 75,000 full cycles.

### 3.3 Cavity Half-Cell Formation

Deep drawing is frequently used method for half-cell fabrication. This process however is mainly used in large-scale production because of the high cost of forming dies. For a limited series of cavity prototypes, spinning or hydroforming is a more preferred method. In addition, experience shows that the final geometry of half-cells formed by spinning may be better controlled. One of the manufacturers of the cavity prototype built under this program chose spinning as the method of half-cell formation. The tolerances in the geometry of the half-cell were met. This method of half-cell formation is relatively inexpensive and rather fast, but requires a constant QA control to ensure proper final geometry. Alternatively, another manufacturer used hydroforming as a method of half-cell formation. Here again, a constant QA control of formation process is required.

### 3.4 Stainless Steel- Niobium joints

The ED&D design calls for Conflat™ flanges to connect the SCRF cavity to the other components. All flanges are made from 304 stainless steel. Since welding of Nb to stainless steel is impossible, brazed joints were developed to join the Conflat™ flanges to Nb tubes. LANL developed a brazing procedure that uses a NIORO™ layer (82% Au+18% Ni). Another manufacturer used a proprietary procedure. Figure 4 shows a brazed, large tuner stainless-steel Conflat™ flange brazed to a Nb beam tube.



Figure 3. Conflat™ 304 stainless-steel flanges brazed to Nb tubes. The large square flange is a tuner flange; the round one is a power coupler flange.

Once the brazing of the stainless-steel Conflat™ flanges to Nb tubes was performed, the manufacturers were requested to test the parts for possible leaks according to

the following procedure: the parts were thermally cycled between 77 K (liquid nitrogen boiling temperature) and 373 K (water boiling temperature), then tested for possible leaks. This operation was performed three times for each brazed joint.

#### 4 TECHNOLOGY TRANSFER PROGRAM

Within the U.S. industry, there is presently little experience in manufacturing a large number of Nb SCRF cavities. Therefore, a special technology transfer program was initiated. For this program, one qualified company with previous experience in fabrication of accelerator components was selected. Company personnel was invited

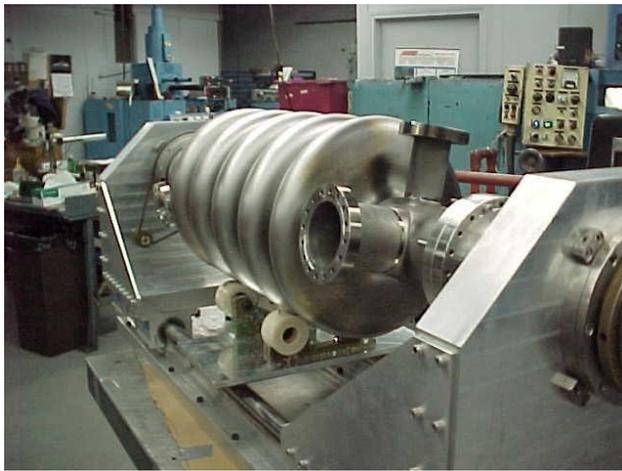


Figure 4. ED&D SCRF cavity prototype fabricated by the U.S. industry

to LANL to witness all steps of fabrication of the LANL cavity prototype, including half-cell formation, buffered chemical polishing, and electron-beam (EB) welding. During their visits, an exchange of information occurred that allowed the potential manufacturer to prepare a realistic manufacturing plan. All manufacturing drawings were supplied with essential fabrication tooling including rotatory welding fixture. After the contract was awarded for the manufacture of a SCRF cavity prototype, members of the SCRF team regularly visited the manufacturer's plants to provide advice on various manufacturing steps, witnessed the progress, and shared experiences. These visits were followed by periodic teleconferences to assess difficulties that might occur, in the process of cavity fabrication, and to ensure the compliance of the final product to SOW requirement. Fig. 4 shows a cavity prototype fabricated through this collaborative effort. The experience gained during this technology transfer program was judged positive by both parties. It suggests that U.S. industry is capable of delivering SCRF cavities for a large accelerator program like APT.

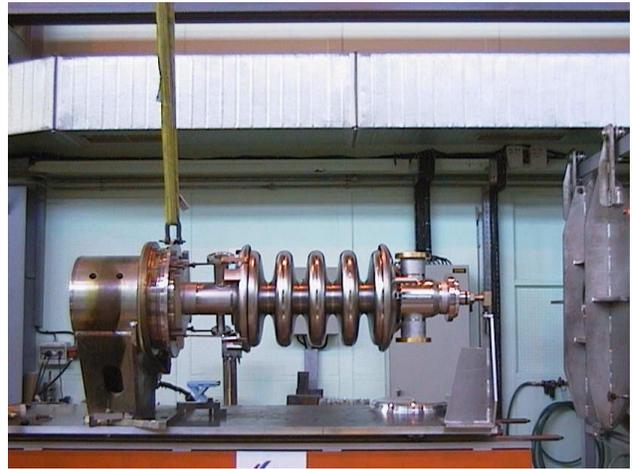


Figure 5. ED&D SCRF cavity mounted for the final EB welding.

#### 5 CONCLUSIONS

Two medium- $\beta$  SCRF cavities were successfully fabricated by industry in the frame of the ED&D program. One cavity, shown in Fig. 5, is the first of four to be manufactured by industry under contract with APT according to the LANL design that incorporates all of the features of the production cavities. These cavities are equipped with the bulkhead-bellow assemblies and dummy tuners. The cavities will be soon cold tested at LANL to determine the accelerating gradient and unloaded quality factor  $Q_0$ . The two best will be selected for use in the assembly of the first APT cryomodule. In addition, a SCRF cavity prototype has been manufactured by U.S. industry in the spirit of technology transfer, using LANL-supplied tooling and expertise. That cavity does not include bulkhead-bellow assemblies or a dummy tuner. The preliminary tests show that the frequency of this cavity and the field flatness meet the requirements of the ED&D program.

#### 6 REFERENCES

- [1] R. Genzlinger, et al. Design, Analysis, and Fabrication of the APT Cavities (Paper No. MOP 127 submitted to this conference.)
- [2] Proceedings of the International Workshops on RF Superconductivity. (Seven published volumes)